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## THE PRINCIPLES OF MECHANICS.

*Newton's Laws of Motion.* By Prof. P. G. Tait. Pp. viii + 52. (London : A. and C. Black, 1899.)

HOW is the science of mechanics to be taught to medical students who have to "get up" natural philosophy in three months? If a teacher, confronted with such a problem, took refuge in sheer "cram," his action could cause no astonishment; an attempt, such as Prof. Tait has made, to provide a solution in which cram has no place commands admiration, even if it cannot be pronounced successful. The author's method is to furnish the student with a set of perfectly recorded lecture notes, and thus leave him free to follow the lectures instead of taking notes of them. Perhaps no better method can be devised, if the substance of the lectures is as good as the record in the notes is perfect, and if the student is made to apply the ideas explained in the lectures to simple examples. The latter of these conditions is doubtless fulfilled in Prof. Tait's classes; we are concerned here with what can be made out in regard to the former. After all the books that have been written on the subject, there was still room for a pointed statement of the principles of mechanics, with sufficient detail and sufficient illustration, but short; and such a summary, if only it were precise and lucid, could not fail to be useful to a class much wider than that immediately in view; but its value would be diminished in proportion as it was marked by vague statement, inexact definition and loose argument.

The work before us begins with three pages of introductory remarks, and these are followed by a chapter on kinematics and a chapter on dynamics. In the introductory pages we find a statement of the laws of the conservation of matter and of energy, and a reference to the laws of the inertia of matter and of the transformation of energy. As a specimen of the dogmatic tone adopted we may quote the following:—

"The objective realities of the physical world are of two kinds only—matter and energy. Our conviction of their objectivity is based on the experimental fact that we cannot alter the quantity of either."

No exception could be taken to this statement if the evidence for it were going to be adduced; and indeed the kind of summary that is likely to be most useful is just one that would trace the operation of the laws of conservation and transformation of energy, and of the law of the inertia of matter, in the processes of everyday experience and in easily observed phenomena. In picking out *mass* and *energy* as the two fundamental conceptions the author is certainly right, but much depends on the way in which they are discussed.

The same wisdom in the selection of the topics to be treated is apparent in the chapter on kinematics, and the arrangement also of these topics is excellent; it is to some of the details that exception must be taken. There is a general discussion of *vectors*, but the definition which is given of a vector is incomplete, and the necessary distinction between a vector associated with a par-

ticular line and one for which all parallel lines are equivalent is not explained. In the definition which is given of the *moment of a vector*, the fact that the rule of signs is a part of the definition is lost sight of, and the reason why the moment itself should be regarded as a vector is obscure. The proof, on p. 20, that angular velocity is a vector involves a *petitio principii*. In this, as in the proof of the parallelogram of velocities, what is most required is an explanation of the sense in which a point can be said to have two simultaneous velocities, or a body two simultaneous angular velocities. The definition of *velocity* is always one of the stumbling-blocks in the way of students; the author avoids giving a definition; he says, "Speed need scarcely be defined, as every one knows what it means." It may be that the writers of current text-books know what it means; they seem quite unable to explain it; nearly all of them proceed in a vicious circle, saying that the velocity of a point when variable is measured at any instant by the space that would be passed over in a unit of time if the velocity continued the same as it is at the instant—as well might one define the curvature of a curve at a point as the angle that would be contained between the tangents at the ends of an arc of unit length if the curvature continued the same all along the arc as it is at the point. If the student is not meek he will ask, "But what is it at the point?" It is only because he thinks he "knows what it means" that he does not ask the like question about speed. Prof. Tait gives countenance to the widely-spread vicious definition without reproducing it. Surely he might have spared some space to explain the mathematical notion of a limit, and to define velocity as a limit. Why do writers of elementary books treat the student as a baby when any limit is in view, and talk to him, for example, about "the next point" to a point on a curve? (p. 9). He knows as well as his teacher that there is no next point. The commonly received absurdities about what are really limiting processes secure acquiescence by frequent repetition, but they foster in the mind of the student a belief in the unreality of the whole business.

The chapter on dynamics suffers from defects which are not merely faults of detail, but arise from the position taken up, viz., that Newton's laws of motion still form the simplest foundation of the subject. Some remarks in Prof. Tait's address to Section A of the British Association in 1871, dealing with the use of Euclid's "Elements" by British mathematicians in the teaching of elementary geometry, apply, with at least equal force, to the use of Newton's laws of motion in the teaching of elementary dynamics. He said of the teachers:

"They seem voluntarily to weight alike themselves and their pupils for the race; and a cynic might, perhaps without much injustice, say they do so that they may have mere self-imposed and avoidable difficulties to face instead of the new, real, and dreaded ones."

The defect of the laws of motion as a statement of the principles of dynamics is not that the principles are not implicitly contained in the laws, but that the principles have to be extracted from the laws, and that the laws themselves are stated in terms of insufficiently defined abstractions. How much of the contents of the

laws of motion is of the nature of definition, and how much is a statement of facts ascertained experimentally, is not disclosed. To assert that these laws still form the simplest foundation for the subject is to ignore the progress that has been made since the publication of Thomson and Tait's "Natural Philosophy." The difficulties into which writers who follow Newton uncritically must needs fall can be illustrated by sentences on pp. 27 and 28. On p. 27 we read, "Force is defined as any cause which alters the momentum of a body"; and on p. 28 we are told that force is "merely another name" for "the vector-acceleration of momentum." This makes the same word do duty for the cause of the change and the rate of the change. Others of the definitions given are wanting in precision. The definition of the *mass* of a body as the quantity of matter in it is a definition of one previously undefined thing in terms of another. The description of the first law of motion as a "statement of the inertia of matter" is not helpful; inertia is a property of matter under ordinary conditions, and the first law is a statement about matter under conditions in which it has never been observed. It ought to be realised that the three laws form a connected system, and that all of them are as much needed as any one of them for the precise definition of *force*, or the exact statement of the inertia of matter. The definition given of *work done* is obscure; the work of a force is defined as a product, and no indication is given of the sense in which this product can be said to be "done." What is wanted here is much the same as in the case of force: we all have an anthropomorphic idea that some cause must operate to start or stop the motion of a body; we have a similar idea that a man has done something when he has lifted a weight or thrown a cricket ball, and these ideas should be taken hold of and made precise by the introduction of measurable quantities which are adequate to represent them.

The difficult ground of definition and statement of principles once covered, the rest of the book is for the most part excellent, the geometrical methods employed being especially elegant. Room is found for an elementary discussion of strain, of compounded simple harmonic motions, of attractions, including the distribution of electricity on a sphere under influence, and of the velocity of waves along a stretched cord, in addition to interesting and unhackneyed accounts of the matters which are the stock-in-trade of books on the elements of mechanics. The book on the whole is thoughtful, in many parts it is much better than the current text-books, and the parts that call for criticism are no worse than the corresponding parts of most other books on the subject; but they are the most important parts, and they might have been so much better. There was a great opportunity, and it has been missed. A. E. H. L.

#### THE SCIENCE OF LAND FORM.

*Physical Geography.* By Prof. W. M. Davis, assisted by W. H. Snyder. Pp. xvii + 428 + 9 plates. (Boston and London: Ginn and Co., 1899.)

AN examination of this volume gives rise to feelings of both congratulation and regret—congratulation that so admirable a manual for the elementary student of

physical geography has been produced, and regret that so little attention is given to the subject in our schools and colleges. Rational methods of instruction are now advocated for all the concrete sciences, and are being extensively applied to physics and chemistry; but geography has only been very slightly benefited by the pedagogic reforms of the last decade, and in the majority of our secondary schools it is still represented by definitions, outline maps, uninteresting statistics, and lists of names which make no real impression upon the minds of the pupils. Physical geography, the elements of which should be presented at the very beginning of the study of the earth, is usually neglected altogether, or taught in a fashion that fails entirely to place pupils in the receptive intellectual attitude reached after sound instruction in any science.

The present position results chiefly from the want of teachers with a broad conception of the field of geographical science. Every teacher is supposed to be qualified to give instruction in geography; and if the word merely signified the description of the political divisions of the earth, any one could put pupils in the way of acquiring that information. But, rightly defined, geography should be the consideration of the earth as the abode of man, and it should comprise the elements of astronomy, physics, meteorology, botany, zoology, and ethnology, as well as knowledge of commerce and government. To present the subject in these broad aspects, the teacher must be inspired by the scientific spirit and have given personal attention to the facts and phenomena of nature; and where such teachers are not available instruction in geography cannot proceed on scientific lines.

The volume under notice provides an admirable means of improving geographical teaching. Prof. Davis is not only an expert in most of the branches of physical geography; he is also a practical teacher who has devoted much attention to the educational side of the subject. The result is that, with the assistance of Mr. Snyder, he has produced what is certainly one of the best manuals of physical geography ever published. The book is well planned, trustworthy, clearly written, and liberally illustrated; it presents the facts of physical geography in such a way that the reader sees them as part of an organic whole—as organised knowledge which constitutes science. The facts are traced backward to their causes and forward to their consequences; indeed the phrase "causes and consequences" has served as a touchstone by which the treatment of each subject has been tested.

The order of treatment is the earth as a globe, the atmosphere, the oceans, and the lands. These facts are not, however, treated in equal detail; indeed, the last part occupies more than four times the number of pages devoted to the three preceding parts taken together. From this it will be seen that the book is not concerned with physiography as it is usually understood in this country, but with the science of land form. In physiography the student receives practical instruction in physics, chemistry, astronomy and cognate sciences before he considers atmospheric phenomena the circulation of water on the land, the earth's solid